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HENDERSON ROAD INJECTION WELL SITE
REPORT ON ADDITIONAL WORK ON EFFLUENT TREATMENT
PILOTING AND OTHER REMEDIAL MEASURES

RECEIVED

JUN -2 1988

1.0 INTRODUCTION

1.1 SCOPE OF WORK

Hazardous Waste Enforcement Branch
EPA - Region III

The scope of this letter report is to provide the following:

1. A listing and brief description of those ground water treatment technologies to be considered for implementation as part of Alternative 7 of the feasibility study.
2. A list of the additional work required, including piloting, that would be needed on each technology prior to the determination of the selected technologies in the remedial design.
3. An outline of test procedures and pilot study protocols to obtain information required to support the decision making process on the selected remedy to be described in the ROD.

1.2 REPORT OBJECTIVE

This information is to be compiled and presented in order to assist EPA in their approach to writing the record of decision (ROD). This is to be accomplished by summarizing the recommended alternative in the feasibility study and describing those steps which should be taken in order to properly identify those technologies which should be considered for implementation to provide the proper level of ground water treatment.

Those technologies which should be considered include those recommended by BCM in the FS, those which were not recommended in the FS but were not screened out, and one technology which was not considered as part of the FS Report.

In addition to those items presented above, the objective of this report is to list and portray the scheduling of design activities and to show how the information gained during design activities can be used to develop the selected remedy.

The progress of additional work relating to design and pilot work for ground water treatment is shown on figure 1-1.

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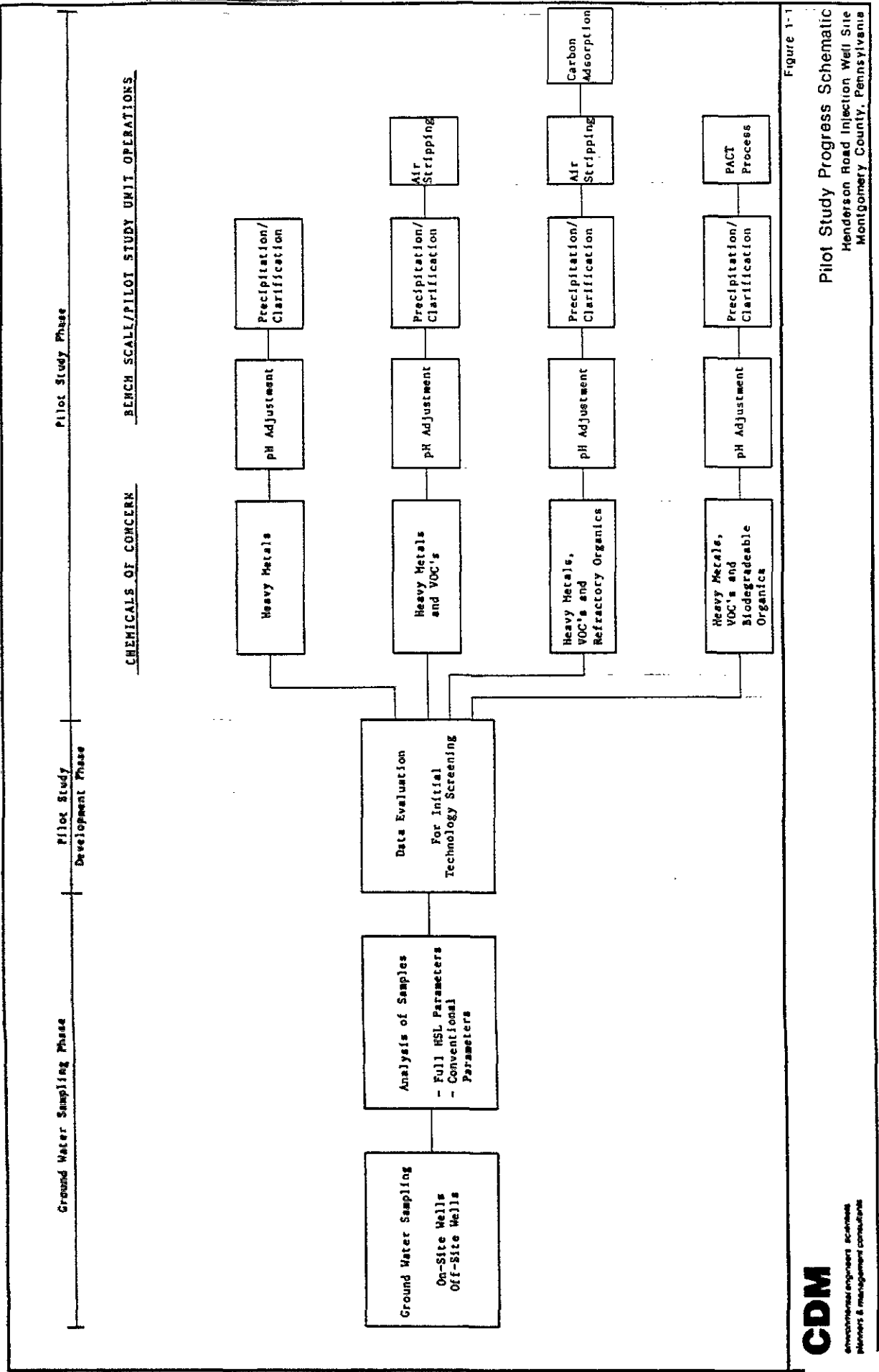


Figure 1-1
Pilot Study Progress Schematic
Henderson Road Injection Well Site
Montgomery County, Pennsylvania

CDM

environmental engineers scientists
managers & management consultants

2.0 GROUND WATER CHARACTERISTICS AND DEGREE OF TREATMENT REQUIRED

2.1 GROUND WATER CHARACTERISTICS

From available maximum contaminant concentration data (Table 2-1), taken from the BCM FS report, it appears that the contamination in on site ground water consists primarily of organics which can be either air stripped, adsorbed or biodegraded.

Table 2-2, also taken from the BCM FS, (which shows the results from sampling done by BCM with split samples taken by Philadelphia Suburban Water Company (PSWC)) indicates that the Upper Merion Reservoir (UMR) contamination consists primarily of low levels of organics that can also be either air stripped, adsorbed or biodegraded.

Other data which are included in the BCM FS describes the water quality at each well sampled both on and off the Henderson Road site. This data may not be representative (especially of off-site ground water quality) however it also shows that contamination is primarily low level organics which can be removed by air stripping, adsorption and biodegradation.

2.2 DEGREE OF TREATMENT REQUIRED

Prior to discharge from any treatment facility the level of treatment required must be defined. Preliminarily it appears that two discharge options exist at the site, discharge to the intermittent stream (which is the preferred alternative) or reinjection to the aquifer either on site or downgradient.

2.2.1 DISCHARGE TO INTERMITTANT STREAM

Preliminarily it appears that discharge to the intermittent stream must at a minimum meet the effluent limits as shown in table 2-3. These requirements, the most stringent requirements presented in the HRIWOU FS would be required in that discharge to this stream would constitute a significant portion of the total flow and should therefore would be expected to meet

TABLE 2-1

SAMPLE DATA SUMMARY - MAXIMUM CONCENTRATIONS OF CONTAMINANTS
IN ONSITE MONITORING WELLS

Compound	Maximum Concentration (ug/l)	Sample Location
<u>Acid Extractable Organics</u>		
Benzoic acid	410.0	HR-2-175
2,4-Dimethylphenol	43.0	HR-2-175
Phenol	28.0	HR-2-175
2-Methylphenol	490.0	HR-2-175
4-Methylphenol	330.0	HR-2-175
<u>Base/Neutral Extractable Organics</u>		
Bis(2-Ethylhexyl)phthalate	18,000.0	HR-2-195*
Butyl benzyl phthalate	210,000.0	HR-2-195*
1,2-Dichlorobenzene	93.1	HR-2-175
1,3-Dichlorobenzene	13.5	HR-3-295
1,4-Dichlorobenzene	74.9	HR-3-295
Di-n-butyl phthalate	3.2	HR-2-276
Di-n-octyl phthalate	2.8	HR-1-260
Naphthalene	12.0	HR-3-295
N-nitrosodiphenylamine	4.0	HR-3-295
Benzyl alcohol	520.0	HR-2-175
4-Chloroaniline	58.0	HR-3-295
2-Methylnaphthalene	10.0	HR-3-295
<u>Volatile Organics</u>		
Benzene	1,700.0	HR-3-295
Chlorobenzene	310.0	HR-2-195*
Chloroethane	2,100.0	HR-4-242
Chloroform	433.0	HR-3-295
1,1-Dichloroethane	2,000.0	HR-RE-205
1,2-Dichloroethane	410.0	HR-2-195*
1,1-Dichloroethene	102.0	HR-3-295
1,2-Dichloropropane	1,800.0	HR-3-295
Ethylbenzene	7,800.0	HR-2-195*
Methylene chloride	850.0	HR-2-195*
Tetrachloroethene (PCE)	9,800.0	HR-2-195*
Toluene	246,000.0	HR-2-195*
Trans-1,2-dichloroethene	785.0	HR-2-175
Trichloroethene (TCE)	610.0	HR-2-175
1,1,1-Trichloroethane	1,200.0	HR-3-295
Trichlorofluoromethane	95.3	HR-3-295
Vinyl chloride	100.0	HR-4-195
m-Xylene	72,000.0	HR-2-175
p-Xylene	19,000.0	HR-2-195*

* HR-2-195 contained a very limited yield of non-aqueous liquid, not representative of onsite groundwater

Source: BCM Eastern Inc. (BCM Project No. 00-5528-03)

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TABLE 2-2

SAMPLE DATA SUMMARY
MAY 1986 SAMPLING OF UNTREATED LMR WATER¹

Compound	BCM (ug/l)	PSWC (ug/l)
<u>Acid Extractable Organics</u>		
Benzoic acid	NA	NR
2,4-Dimethylphenol	ND	NR
Phenol	ND	NR
2-Methylphenol	NA	NR
4-Methylphenol	NA	NR
<u>Base/Neutral Extractable Organics</u>		
Bis(2-Ethylhexyl)phthalate	ND	NR
Butyl benzene phthalate	ND	NR
1,2-Dichlorobenzene	ND	0.24
1,3-Dichlorobenzene	ND	NR
1,4-Dichlorobenzene	ND	0.24
Di-n-butyl phthalate	ND	NR
Di-n-octyl phthalate	ND	NR
Naphthalene	ND	NR
N-nitrodiphenylamine	ND	NR
Benzyl alcohol	NA	NR
4-Chloroaniline	NA	NR
2-Methylnaphthalene	NA	NR
<u>Volatile Organics</u>		
Benzene	ND	0.42
Chlorobenzene	3.2	0.25
Chloroethane	ND	NR
Chloroform	ND	ND
1,1-Dichloroethane	ND	<1.0
1,1-Dichloroethene	ND	NR
1,2-Dichloropropane	ND	NR
Ethylbenzene	13.3	NR
Methylene chloride	3.3	NR
Tetrachloroethene (PCE)	3.6	1.8
Toluene	2.9	1.0
Trans-1,2-dichloroethene	ND	0.35
Trichloroethene (TCE)	12.9	10.0
1,1,1-Trichloroethane	4.9	3.3
Trichlorofluoromethane	ND	NR
Vinyl chloride	ND	<1.0
m-Xylene	ND	NR
p-Xylene	ND	NR

1 - Split samples analyzed by BCM and PSWC
NA - Not analyzed for
ND - Not detected
NR - Not reported by PSWC

Source: BCM Eastern Inc. (Project No. 00-5528-03)

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TABLE 2-3

PROPOSED CHEMICAL SPECIFIC ARARs FOR
A CLASS IIA AQUIFER

Parameter (ug/l)	ARAR (ug/l)	Method/ Source
<u>Metals</u>		
Arsenic	50.0	MCL
Cadmium	10.0	MCL
Chromium	50.0	MCL
Copper	1,300.0	MCLG
Lead	20.0	MCLG
Silver	50.0	MCLG
Zinc	5,000.0	Mc
<u>Other Parameters</u>		
Cyanide	200.0	AHQc
<u>Acid Extractable Organics</u>		
Benzoic Acid	700.0	Ma
2,4-Dimethylphenol	400.0	AHQc
Phenol	3,500.0	DWEL
2-Methylphenol	42.0	Ma
4-Methylphenol	72.0	Ma

MCL - Maximum Contaminant Levels

MCLG - Maximum Contaminant Level Goals

AHQc - Ambient Water Quality Criteria

SNARL - Suggested No Adverse Effect Level

DWEL - Drinking Water Equivalent Level

EPA - Recommended by EPA

Ma - Model in Appendix A of RI

Mc - Organoleptic

*** - EPA Superfund Public Health Evaluation Manual, DER, Washington DC
EPA 54011 - 861060 (OSWER Directive 9,285.4-1), October 1986

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TABLE 2-3 (cont.)

Parameter (ug/l)	ARAR (ug/l)	Method/ Source
<u>Base/Neutral Extractable Organics</u>		
Bis(2-ethylhexyl)phthalate	512.0	
Butyl Benzyl Phthalate	820.0	Ma
1,2-Dichlorobenzene	620.0	MCLG
1,3-Dichlorobenzene	470.0	AWQC
1,4-Dichlorobenzene	75.0	MCL
Di-n-butyl phthalate	770.0	SNARL
Naphthalene	350.0	Ma
N-nitrosodiphenylamine	71.0	***
Benzyl alcohol	364.0	Ma
4-Chloroaniline	35.0	Ma
2-methylnaphthalene	1,750.0	Ma
<u>Volatile Organics</u>		
Benzene	5.0	MCL
Carbon Tetrachloride	5.0	MCL
Chlorobenzene	60.0	MCLG
Chloroethane	19,000.0	EPA
Chloroform	100.0	MCL ¹
Dibromochloromethane	100.0	MCL ¹

MCL - Maximum Contaminant Levels

MCLG - Maximum Contaminant Level Goals

AWQC - Ambient Water Quality Criteria

SNARL - Suggested No Adverse Effect Level

DWEL - Drinking Water Equivalent Level

EPA - Recommended by EPA

Ma - Model in Appendix A of RI

Mc - Organoleptic

*** - EPA Superfund Public Health Evaluation Manual, DER, Washington DC
EPA 54011 - 861060 (OSWER Directive 9,285.4-1), October 1986

(1) - This is MCL for total trihalomethanes

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TABLE 2-3 (cont.)

Parameter (ug/l)	ARAR (ug/l)	Method/ Source
Dichlorobromomethane	100.0	MCL
1,1-Dichloroethane	3.8	***
1,2-Dichloroethane	5.0	MCL
1,1-Dichloroethene	7.0	MCL
1,2-Dichloroethene	70.0	MCLG
1,2-Dichloropropane	6.0	MCLG
Ethylbenzene	680.0	MCLG
Methylene Chloride	47.0	***
Tetrachloroethene (PCE)	5.9	***
Toluene	2,000.0	MCLG
Trichloroethene (TCE)	5.0	MCL
1,1,1-Trichloroethane	200.0	MCL
Trichlorofluoromethane	12,000.0	EPA
Vinyl Chloride	2.0	MCL
m-Xylene	175.0	DWEL
p-Xylene	175.0	DWEL

MCL - Maximum Contaminant Levels

MCLG - Maximum Contaminant Level Goals

AWQC - Ambient Water Quality Criteria

SNARL - Suggested No Adverse Effect Level

DWEL - Drinking Water Equivalent Level

EPA - Recommended by EPA

Ma - Model in Appendix A of RI

Hc - Organoleptic

*** - EPA Superfund Public Health Evaluation Manual, DER, Washington DC

EPA 54011 - 861060 (OSWER Directive 9,285.4-1), October 1986

(1) - This is MCL for total trihalomethanes

the strictest available standards. It may be possible that some standards in table 2-3 which were established based on MCLs may actually be required to meet Ambient Water Quality Criteria (AWQC) for any instance where AWQC are more stringent than MCLs.

2.2.2 REINJECTION TO THE AQUIFER (ON SITE OR DOWNGRAIENT)

Reinjection to the aquifer, it appears, will also have to meet the standards presented in table 2-3. BCM values which are shown on table 1-20 of the FS report which are based on a dilution factor may be acceptable, however those levels have not been accepted by Pennsylvania DER.

2.3 EFFECT OF DISCHARGE OPTION ON LEVEL OF TREATMENT

In the FS report for the site, the preferred final location for effluent discharge is identified as the intermittent stream. However, it is important to note that treatment requirements may be greatly reduced (i.e., made less stringent) if those values which are suggested in Table 1-20 of the FS report can be used or increased significantly if AWQC are required for discharge. Because of the potential for changes in the level of treatment exists, it is recommended that the final discharge location for treated effluent be established at an early stage of the pilot/design work, so that the proper level of treatment can be established and provided with little delay.

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3.0 LISTING OF GROUND WATER TREATMENT TECHNOLOGIES

3.1 GROUND WATER TREATMENT TECHNOLOGIES RECOMMENDED BY BCM

The following three technologies were identified as comprising the recommended alternative in the HRIWOU Feasibility Study.

- 1) pH Adjustment
- 2) Sedimentation/Precipitation
- 3) Air Stripping

3.2 GROUND WATER TREATMENT TECHNOLOGIES NOT RECOMMENDED BUT NOT SCREENED IN THE FS

The following two technologies were not identified as part of the recommended alternative, but were not screened out during the FS.

- 1) Granular Activated Carbon (GAC)
- 2) PACT Process

3.3 GROUND WATER TREATMENT TECHNOLOGIES OMITTED IN THE FS AND SUGGESTED FOR INCLUSION

The following technologies were either not considered for use as part of any alternative or screened out as not being required in the HRIWOU FS. However, it is CDM's judgement that their use would be appropriate as part of a preferred alternative.

- 1) Filtration
- 2) Vapor Phase Carbon Adsorption

Table 3-1 lists those technologies which should be considered as part of the design phase pilot studies.

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TABLE 3-1

GROUND WATER TREATMENT TECHNOLOGIES FOR
CONSIDERATION IN DESIGN PHASE PILOT STUDIES

pH Adjustment

Sedimentation/Precipitation

Air Stripping

Granular Activated Carbon Adsorption (GAC)

PACT Process

Filtration

Vapor Phase Carbon Adsorption

(311/19)NY-SS

4.0 INFORMATIONAL NEEDS PRIOR TO PILOTING/FULL SCALE DESIGN

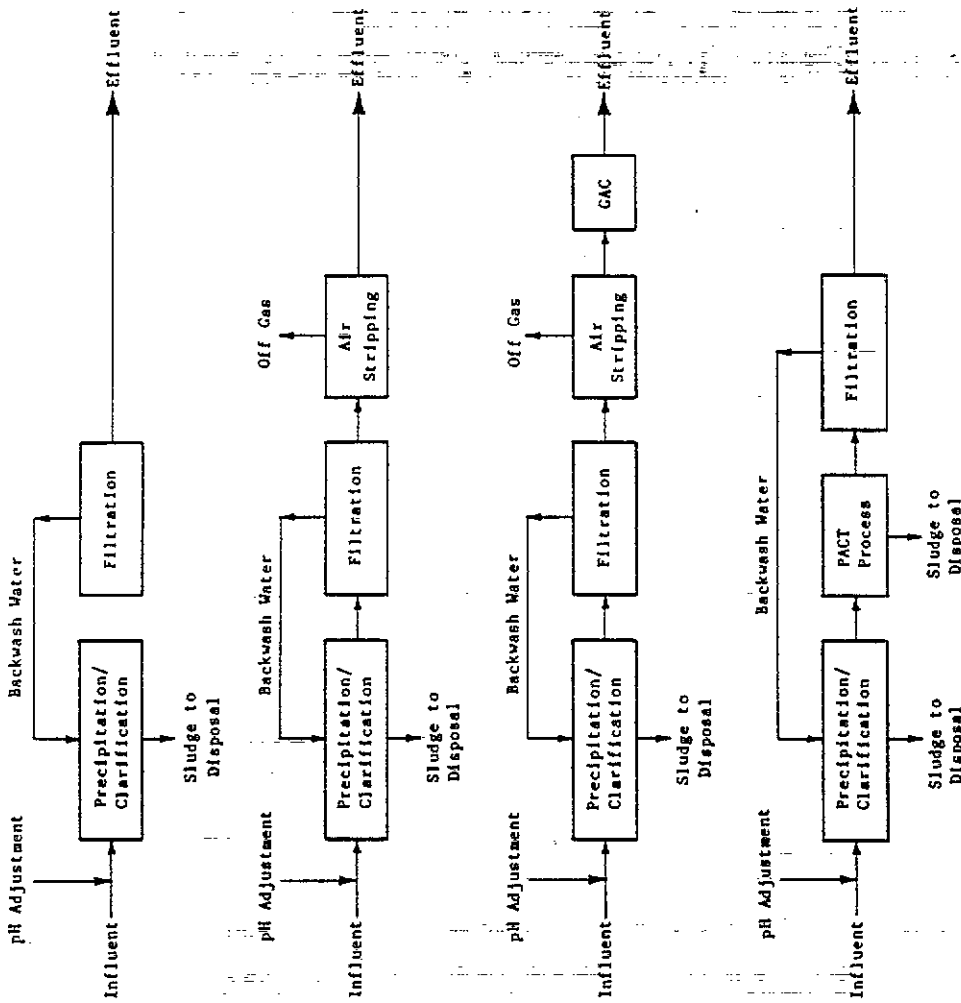
4.1 ADDITIONAL GROUND WATER SAMPLING ROUND

Prior to piloting/full scale design a complete round of ground water samples should be taken. The objective of this sampling round would be to determine whether the technologies presented in the FS should be considered further.

On-site and off-site wells should be sampled and the average of each respective group should be calculated using an arithmetic mean. The parameters to be tested should include, in addition to full HSL parameters:

- o BOD₅
- o COD
- o Ammonia-N
- o Phosphates
- o pH
- o TSS
- o TS
- o TDS
- o Oil and Grease
- o Alkalinity
- o Hardness

Based on the results of this sampling round the required pilot program processes can be determined. The potential treatment options and process schematics are shown on figure 4-1. In addition, certain technologies may be screened without the use of a pilot testing program using the criteria in the following sections.



1. If heavy metals removal is the only concern based on the initial sampling results then the following should be piloted.
2. If heavy metals and VOCs are the concern then the following should be piloted.
3. If heavy metals, VOCs and refractory organics are the concern then the following should be piloted.
4. If heavy metals, VOCs and biodegradable organics are the concern then the following should be piloted.

Note: BCM's preferred alternative is essentially #2 (without filtration). The other three treatment trains are developed from technologies which have passed BCM's screening but were not preferred.

CDM

environmental engineers, scientists,
planners & management consultants

Pilot Study Process Schematics

Figure 4-1

Henderson Road Injection Well Site
Montgomery County, Pennsylvania

4.2 PRELIMINARY SCREENING BASED ON GROUND WATER SAMPLING RESULTS

Based on the results of the additional round of ground water sampling, a preliminary screening of technologies can occur.

4.2.1 NEUTRALIZATION/pH ADJUSTMENT

If the average pH is beyond the range of 6-8, neutralization should be considered. If the pH is within the 6-8 range, then neutralization should not be considered further unless it is required for the settling/precipitation process.

4.2.2 SETTLING/PRECIPITATION

If the total suspended solids (TSS) of the ground water are greater than 100 mg/l, settling/precipitation should be considered. If the TSS are less than 100 mg/l and no metals concentrations appear to be in excess of established discharge limits direct filtration of solids should be considered.

4.2.3 PACT PROCESS

If the average BOD of the ground water is greater than 50 mg/l the contaminated ground water may be able to support biological growth and the PACT activated sludge process should therefore be considered further. If the average BOD is less than 50 mg/l this process should not be considered further.

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5.0 TECHNOLOGY DESCRIPTIONS, TEST PROTOCOLS AND PROCEDURES FOR PILOT AND DESIGN WORK

The following sections provide technology descriptions, design criteria, test protocols and procedures for pilot and design work. Design criteria for the various technologies are presented in the following sections, while each criterion and its use in design is summarized in table 5-1.

5.1 NEUTRALIZATION/pH ADJUSTMENT

Neutralization is used to adjust the pH of a waste stream to an acceptable level for discharge or treatment. Neutralization can be used either pre- or post-treatment. The pH is adjusted by adding acidic reagents to alkaline waste streams and vice versa. This process can be used to treat aqueous, leachate streams. The selection of reagents depends on cost, since purchase and storage of chemicals is a major component of operation and maintenance costs.

5.1.1 DESIGN CRITERIA

The parameters required for design of a system for influent neutralization include:

1. Chemical Type
2. Chemical Dosage
3. Mixing Requirements

5.1.2 OUTLINE TEST PROTOCOLS

Neutralization/pH Adjustment testing should be done on a bench scale for the purpose of determining the type and quantity of chemical required to meet the potential process pH adjustment needs. The bench scale protocol should include eight titrations (two titrations performed on each of two on-site and two down gradient samples). One of the two titrations should be with sulfuric acid to bring the sample to a pH of 4 to establish the alkalinity of the ground water and determine acid addition requirements, if

TABLE 5-1

DESIGN CRITERIA AND THEIR USE IN DESIGN FOR PROPOSED
GROUND WATER TREATMENT TECHNOLOGIES

Technology	Design Criteria	Use In Design
Neutralization/ pH Adjustment	Chemical Type	Effects potential effluent quality and chemical handling requirements.
	Chemical Dosage	Effects chemical storage volume and ultimate cost of technology.
	Mixing Requirements	Effects mixing tank sizes or length of static mixers.
Settling/ Precipitation	Chemical Type	Effects settling velocity and sludge quality.
	Chemical Dosage	Effects effluent quality, sludge volume and settling rate.
	Flocculation Time	Effects size of flocculation tanks and rate of floc formation.
	Agitation Rate	Effects floc formation and settleability of solids.
	Detention Time/ Overflow Rate	Effects settling tank size and effluent quality.
	Sludge Production Rate	Effects sludge storage and disposal requirements.

TABLE 5-1 (cont'd)

DESIGN CRITERIA AND THEIR USE IN DESIGN FOR PROPOSED
GROUND WATER TREATMENT TECHNOLOGIES

Air Stripping	Flow Rate	Effects pumping requirements and tower diameter.
	Liquid Loading Rate	Effects tower diameter.
	Air To Water Ratio	Effects removal rate and blower capacity.
	Required Removal Efficiency	Effects tower height.
	Packing Type	Effects removal efficiency and hydraulic capacity.
	Tower height	Effects tower height and pumping requirements.
Carbon Adsorption	Flow Rate	Effects carbon bed size and empty bed detention time.
	Empty Bed Detention Time	Effects scale up of full scale system.
	Liquid Loading Rate	Effects carbon bed diameter.
	Breakthrough Time	Effects frequency of carbon replacement.
PACT Process	Flow Rate	Effects size of process tankage.
	Required Carbon Dosage	Effects costs and organics removal.
	Required MLSS	Effects biological organism growth rate.
	Required Nutrient Additions	Effects biological organism growth rate.

TABLE 5-1 (cont'd)

DESIGN CRITERIA AND THEIR USE IN DESIGN FOR PROPOSED
GROUND WATER TREATMENT TECHNOLOGIES

Hydraulic Retention Time/ Cell Retention Time	Effects sludge production and quality.
Sludge Production Rate	Effects storage and disposal requirement.

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any, and one with sodium hydroxide to a pH of 11 to establish the requirements for base addition. The sample size for each titration should be a minimum of 100 ml.

5.2 SETTLING/PRECIPITATION

Settling/Chemical precipitation is often used for the removal of solids, hardness and heavy metals and involves a reaction between any ion in the water by a counter-ion, forming an insoluble product that precipitates from solution. Such a reaction can be initiated by pH adjustment, introduction of the counter-ion, or by changing the oxidation state of a metal. For example, iron in ground water is usually found as ferrous ion. By adding an oxidizing agent such as chlorine or by aerating the water, the ferrous ion is oxidized to ferric, which then precipitates from solution as ferric hydroxide. In contrast, removal of hardness, either calcium or magnesium, requires the introduction of an appropriate anion. For example, magnesium can be precipitated from the water by increasing the pH as magnesium hydroxide. Lime, a strong base, is usually added to the water to provide the hydroxides. Concurrently, if the water contains a sufficient amount of alkalinity, the increase in pH transforms bicarbonate alkalinity into carbonates, which will precipitate the calcium hardness. Water that does not contain sufficient alkalinity, in addition to lime, requires the addition of soda ash to precipitate the calcium hardness. The chemical reactions associated with total hardness removal should also be effective in the removal of other cationic species. It should be realized that chemical precipitation may not remove all the ions of concern. However, this type of process can be used to reduce their concentration to acceptable levels.

Sedimentation usually represents the first attempt to remove the suspended solids, and subsequent sand filtration removes the remaining suspended solids.

Sand filtration involves removal of suspended solids by entrapment following treatment by flocculation/sedimentation. The process loading rates, backwash requirements, design concepts, and the operation of the filters

are well understood and can readily be applied to ground water treatment. Filtration is feasible when the nature of the suspended solids in the feed water supports a long filter run which is likely when used for ground water treatment.

Adoption of filtration will not require a pilot study. Sufficient data are available in the literature to support design and selection of filter type. Filtration for this project would be designed to support other processes as a polishing step subsequent to precipitation, flocculation, and sedimentation. Modular units are available from several manufacturers.

Chemical precipitation is a proven technology that has been demonstrated in numerous water treatment plants where water softening is practiced. It is effective in reducing the hardness and removing many inorganics to acceptable levels in the ground water.

5.2.1 DESIGN CRITERIA

The parameters required for design of a chemical precipitation/settling system include:

1. Chemical Type
2. Chemical Dosage
3. Flocculation Time
4. Agitation Rate (GT)
5. Detention Time/Over Flow Rate
6. Sludge Production Rate

5.2.2 OUTLINE TEST PROTOCOLS

Settling/Precipitation testing should be conducted on a bench scale. Based on the data presented in the FS it is assumed that there will be no significant problem associated with the heavy metals in the ground water at the site although this would be determined during the initial sampling round. Problems that are expected may be due to suspended solids, iron and hard-

ness. The objective of the testing will be to determine the appropriate chemical type and dosage required for the pretreatment of influent ground water.

The bench scale testing should include the consideration of 4 different chemicals. Suggested chemicals include; alum, ferric chloride, lime and polymer. The bench scale protocol should use jar test methods with a minimum of six jars per test. The sample size tested should be approximately 1000 ml. Analysis should be performed on each of the jars and a raw sample for, at a minimum, TSS, turbidity, alkalinity, pH, and specific heavy metals as required. The sludge produced in each jar should also be sampled for pH, specific gravity, TSS and specific heavy metals. The optimum dosage and chemical should be selected on the basis of most effective solids removal considered in light of chemical cost and sludge disposal requirements.

5.3 AIR STRIPPING

Air stripping is a proven, effective treatment process employed to remove volatile compounds from ground water, by bringing contaminated ground water into direct contact with air, so that volatile compounds move from the liquid phase to the vapor phase. Once in the vapor phase, the air can then carry off the contamination, leaving the water free of these compounds.

Air stripping can be accomplished by several methods. The method chosen depends upon the nature and duration of the cleanup project. There are two basic types of aeration equipment currently used for water treatment: (1) diffused aerators, in which bubbles of air are passed up through the water and (2) cascading aerators, such as multiple-tray towers, spray nozzles, and packed towers. For application at the Henderson Road site only packed towers will be considered.

A packed tower is a method of air stripping that has found great acceptance for both potable water purification and remediation of ground water contamination. Packed towers utilize a countercurrent flow scheme in which water enters at the top of the tower and flows downward through a packing

material, while the airstream flows upward, removing the volatile compounds in the process. Effluent water is collected at the bottom of the tower in a wet well and is pumped to its final destination. The air exits at the top of the tower and is dispersed, along with the volatiles, into the atmosphere or treated with vapor phase carbon. In these systems the tower packing material serves to break water into small droplets, resulting in continuous and thorough contact of the liquid with the gas and minimizing the thickness of the water layer on the packing, which promotes efficient mass transfer. In addition, greater air-to-water ratios can be achieved with a packed column because of low air pressure drops through the towers. Packed-column aeration has been demonstrated to provide a cost-effective system for removing volatile organics from ground water.

In designing a packed column for a selected media, three basic variables must be defined: (1) tower height, (2) tower diameter, and (3) air-to-water ratio. Although these variables are dependent upon each other, the following relationships are helpful in calculating preliminary sizing estimates:

- Tower diameter is most strongly a function of flow rate.
- Tower height is most strongly a function of removal efficiency required.
- Air-to-water ratio is a function of the specific contaminant to be removed.

The design method for any packed column starts with the mass transfer process. The rate of transfer of the VOCs will be a function of the concentration gradient between water and air and the air-water interface area. Different compounds will be transferred from the liquid to gas phase at different rates, depending on the Henry's Law constant of the particular compound. Compounds with high Henry's Law constants are easily removed because they have a greater concentration in air when an air-water system is in equilibrium. Compounds with low Henry's Law constants have a greater concentration in water and are more difficult to remove by these methods. The air emissions that are created by the discharge of volatile organics from packed towers are a major concern. In any air stripping process, contaminants are not destroyed in the transfer process; they are merely

transferred to the air stream. It is important to note, however, that there are mitigating effects to these potentially high atmospheric discharges. Air-to-water ratios commonly used range from 25:1 to 250:1, so contaminants are diluted by a similar factor when transferred to the air. In addition, natural dilution occurs when the airstream from the tower is dispersed into the atmosphere. Furthermore, many organic compounds such as trichloroethene and tetrachloroethene will break down in the atmosphere under the effects of solar radiation. Although these effects are advantageous, it is often necessary to treat the exhaust gases from these towers by discharging them through air pollution control devices such as vapor phase carbon. The use of a vapor phase carbon adsorption system would be determined during pilot testing of any air stripper.

Packed towers have been used in many ground water treatment facilities to remove volatile organics. The combination of high removal efficiency, low cost, ease of operation, and the wide variety of compounds that can be removed from ground water by these towers make this technology an appropriate choice for treating many contaminant streams.

5.3.1 DESIGN CRITERIA

The parameters required for the design of an air stripping tower include:

1. Flow Rate
2. Liquid Loading Rate
3. Air to Water Ratio
4. Required Removal Efficiency
5. Packing Type
6. Tower Height

5.3.2 OUTLINE TEST PROTOCOL

Air stripper pilot testing should be conducted for the purpose of obtaining information regarding the removal of volatile and semivolatile organics from the site ground water. The air stripping pilot testing should be run

on a minimum 6 inch diameter, 12 foot high air stripping tower with a minimum of 8 feet of packing material. The flow rate through the tower should be between 5 and 10 gpm and blowers for the tower should be capable of providing air flow between 10 to 150 scfm. During piloting vapor phase carbon units should be used to collect tower off gas so that air quality standards are not exceeded. The use of vapor phase carbon in a full scale system would be determined during the pilot study by sampling the influent and effluent air streams to determine if tower off gas would exceed standards. The air stripping tower should be operated at surface loading rates of between 10 and 50 gpm/ft² and volumetric air to water ratios of between 20 and 100. If a larger diameter column is used, then the water and air flow rates must be adjusted. It should be stated that a larger diameter column will produce better data and more testing flexibility. However it will mean that larger volumes of water must be handled during the pilot study. In order to optimize the removal of semivolatile compounds inlet water temperature may also be varied between ambient and 160°F. During piloting inlet and outlet tower and ambient air and water temperatures should also be monitored. During the pilot testing samples should be taken for volatile and semivolatile organics from both the influent and effluent air and water. If inorganic or solids removal is determined to be required on the air stripper influent as a result of other pilot tests, then the air stripping tower should be preceded by a solids removal system. By providing a solids removal unit, the air stripper influent quality will then be closer to what would be expected during full scale operation, thus providing more reliable pilot study results.

5.4 CARBON ADSORPTION

Granular activated carbon (GAC) adsorption has been used by industry for many years in order to remove a wide variety of dissolved organic contaminants from ground water. Carbon adsorption is a highly effective removal technology for compounds that may not be removed by air stripping or other methods. In the United States, GAC has traditionally been used in the treatment of drinking water supplies for taste and odor control. However, recent studies have focused on its application for the removal and control of organic contaminants in ground water supplies.

The first step in evaluation of activated carbon adsorption for a specific contaminant is to assess its feasibility utilizing available liquid-phase adsorption isotherms. Adsorption isotherms are useful for obtaining preliminary data concerning GAC treatment to remove organics. These isotherms do not yield sufficient data to develop design criteria for GAC systems, but they do provide information about its feasibility for use. In order to develop design criteria, a pilot-scale carbon column test is often necessary.

Carbon adsorption is a relatively expensive ground water treatment process. However, the inherent advantages of the technology make it particularly suited for low concentrations of nonvolatile components, high concentrations of nondegradable compounds and short-term projects. Carbon adsorption also serves as a complementary technology used to treat air stripping effluent water; it is used to remove high-molecular-weight volatile organics and nonvolatile components. GAC is often used to clean affected ground waters to the lowest possible levels before discharge to distribution systems.

5.4.1 DESIGN CRITERIA

The parameters required for the design of a carbon adsorption column include:

1. Flow Rate
2. Empty Bed Detention Time
3. Liquid Loading Rate
4. Breakthrough Time

5.4.2 OUTLINE TEST PROTOCOL

The carbon adsorption pilot testing should be run using both a bench scale study and a pilot scale continuous flow system that models full scale operation. This system may include a unit for settling/precipitation as well as an air stripper prior to carbon adsorption, although the makeup of this system would be based on prior testing. The bench scale study should

include the determination of removal isotherms for six contaminants (2 VOCs, 2 base/neutral extractables and 2 acid extractables).

To determine the carbon usage rate for contaminant removal, pilot scale carbon columns should be operated at a flow rate of 1 to 5 gpm/ft² continuously 24 hours a day for 14 to 28 days. Influent and effluent samples shall be taken from the columns and analyzed for TOC, VOCs, BNAs and Metals. These tests should be designed to provide data for the determination of the required contact time and hydraulic loading rate as well as the associated breakthrough curves for various contaminants.

5.5 ACTIVATED SLUDGE (PACT PROCESS)

The PACT (powdered activated carbon treatment) wastewater treatment process involves the addition of powdered activated carbon to the aeration basin of a biologically activated sludge system. The combination of physical adsorption with biological oxidation and assimilation has been shown to be effective in treating wastewaters of variable concentration and composition, including highly colored wastewaters or those containing toxic compounds. The following advantages of the PACT wastewater treatment process have been noted:

- o High BOD and COD removals
- o Stability of operation with variability in influent concentration and composition
- o Enhanced removal of toxic substances
- o Improved solids settling
- o Suppression of organics volatilization

Pilot studies for leachate treatment have been successful. Leachates of variable strength can be treated by varying the carbon dosage. The process is somewhat more complex to operate than a conventional activated sludge wastewater treatment plant since it includes carbon addition and may include pH control and nutrient addition. Zimpro, Inc., which holds a license for this process, indicate 95 percent removal of toxic organics and 25 mg/l biochemical oxygen demand (BOD) in the effluent are achievable.

5.5.1 DESIGN CRITERIA

The parameters required for the design of an activated sludge (PACT) process include:

1. Flow Rate
2. Required Carbon Dosage
3. Required MLSS
4. Required Nutrient Additions
5. Hydraulic Retention Time/Cell Retention Time
6. Sludge Production Rate

5.5.2 OUTLINE TEST PROTOCOL

The PACT process piloting should be considered if the average BOD of the sample taken during the initial full scale sampling is in excess of 50 to 100 mg/l. The bench scale study would be designed to determine the size of the aeration tank, the powdered carbon dosage and other optimum operating parameters.

The study involves a continuous feed reactor operated over a period of 60 days. The flow rate should be in the range of 3 to 4 liters per day. the mixed liquor suspended solids (MLSS) should be in the range of 3000 - 4000 mg/l. The reactor should be seeded with return sludge from a nearby secondary wastewater treatment facility. Initially the reactor should be operated without any carbon dosage, the clarified effluent from the aeration tank should be monitored for the chemicals of concern and if the treatment objectives are not achieved then powdered carbon should be added to the aeration tank incrementally until the effluent quality meets the objectives.

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6.0 MCILVAIN TREATMENT SYSTEM RECOMMENDATIONS

As described in the HRIWOU FS the McIlvain water supply would be treated at the point of use by an activated carbon adsorption system. This system is expected to be capable of reducing the risk due to the use of this well from greater than 1×10^{-6} to below this level.

The type of activated carbon system described in the FS appears to be the type commonly used in household applications and is likely to be effective for the removal of those contaminants which are currently found in the well water. The critical operating parameter of the proposed McIlvain well treatment system would be the frequency of carbon replacement. This can be simply determined using the results of well sampling and commonly available removal data.

Based on the data which is currently available it appears that pilot testing would not be required prior to design of the McIlvain treatment system.

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